Simulation Modelling Practice and Theory 18 (2010) 1428–1441

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

Simulating the dynamic scheduling of project portfolios

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ARTICLE INFO

Article history:
Received 15 November 2009
Received in revised form 16 April 2010
Accepted 21 April 2010
Available online 27 April 2010

Keywords:
Dynamic multi-project scheduling
Portfolio management
Agent-based simulation

ABSTRACT

A main challenge in project management is to provide methodologies that facilitate coordination among the projects in a portfolio or in a firm. Each incoming project in an existing portfolio affects its schedule, the resources availability and the planned performance. There are no analytical solutions for the problem of dynamic scheduling of resources for multiple projects in real time. Mathematical approaches, like integer programming or network based techniques, cannot describe the complexity of real problems (multi-projects environments have many interrelated elements), and have difficulties to adapt the analysis to dynamic changes.

We propose a multi-agent system, where projects negotiate the procurement of resources through an auction mechanism all over the portfolio life. Both, projects and resources are modelled as agents. Projects demand resources for fulfilling their scheduled planned work, whereas resources offer their capabilities and workforce. This framework allows project portfolio management and the assessment in the decision of acceptance/rejection new projects.

1. Introduction

In the XXI century firms are adopting projects, programs and portfolios to meet their strategic, operational and tactical goals. Providing methodologies suitable for dealing with simultaneous management of multiple projects –differing in terms of size, required skills and urgency – remains as a main challenge for project management [25]. Firms create portfolios looking for benefits (synergies) from global coordination among projects, but some issues are not yet solved, as the dynamic multi-project scheduling.

The decision to accept a new project mainly depends on its economic feasibility, its strategic importance and its scheduling feasibility. But incoming projects affect and are affected by the rest of the projects in the portfolio. Once a new project is accepted and incorporated to an existing portfolio, we have to update the projects task schedules and the expected return to be ready for new project acquisitions.

Previous decisions have high impact on the office's profit. In order to achieve strategic goals it is important to give priority to projects, and to allocate activities to the most efficient workers at the appropriate time. Because of this, before executing projects it is advisable to make a schedule that optimizes the allocation of resources.

Classical methods, based on mathematical programming, can help to make those decisions when problem complexity is low and the system organization is rather static. But these techniques are not flexible or robust enough, and have difficulties to consider many real factors. In addition, real environments undergo frequent changes (new resources, new technologies) that force to modify the scheduling system.

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doi:10.1016/j.simpat.2010.04.008

These issues have motivated, in last years, the development of new proposals for improving scheduling and control in multi-project environments. The paradigm of multi-agent systems (MAS) can help to find solutions, especially in cases where some social behaviour emerges. This paper shows an agent based approach for online dynamic scheduling and control in multi-project environments that takes advantage of the ability of agents to negotiate and adapt to changing conditions. The MAS has basically two types of agents: projects managers and resources managers.

Projects have scheduled work to be done by different resources. Resources are endowed with some capabilities (knowledge, work force, etc.) that are needed to do the work. Projects demand resources over time and resources offer their capabilities and time availability. There is an auction process, and the price of resource-time slots emerges endogenously as a result of supply and demand.

The rest of the paper is organized as follows. In the next section we discuss the problem of multi-project scheduling and the applicability of agent based simulation. Section 3 shows the MAS we have developed to provide real time evaluation of projects and the portfolio scheduling problem. Agents participate in a 'virtual market' that allows an efficient allocation of resources for project tasks which is explained in Section 4. The simulation of different scenarios and results are described in Section 5. Finally, we summarize the main conclusions in Section 6.

2. Related works: dynamic multi-project scheduling and multi-agent systems

The problem of allocating resources for multiple concurrent projects appears in large cases of service and manufacturing organizations. These organizations manage a wide variety of projects with different starting and due dates and variable makespan, but they share different resources to fulfil different tasks.

Project scheduling research has been a main area of interest in the last two decades. The Resource Constrained Project Scheduling Problem (RCPSP) has become a standard model for project scheduling which belongs to the class of the strongly NP-hard problems [4,20]. But this model cannot deal with all the situations that occur in real world, and many authors have extended it by simulation to develop more general project scheduling problems (a survey is provided by [12]) or applying multi-agent systems (MAS) [31]. It has been characterized as the Decentralized Resource Constrained Multi-Project Scheduling Problem (DRCMPSP) by Confessore et al. [7].

That problem can be solved by classical methods based on mathematical programming when problem complexity is low and the system organization is rather static. There are some heuristics and meta-heuristics that are able to provide good schedules for more complex problems [24]. The traditional scheduling and control systems propose hierarchical and centralized architectures, where a classical scheduler system – that has a global model of the multi-project environment – makes schedules according to the current state of the system. Hans et al. [11] review existing literature in hierarchical approaches and propose a generic project planning and control framework for helping managers to choose between planning methods, depending on organisational issues. But these techniques are not flexible or robust enough, and have difficulties to consider many real factors. The traditional scheduling and control systems based on hierarchical and centralized architectures are not flexible enough to adapt themselves to the dynamism and complexity needed multi-project environments.

The application of simulation techniques has widely benefited scheduling problems in general, and more specifically project management planning and control and multi-project management (a detailed and recent survey about in [16]). The use of agent-based simulation (ABS) to deal with complex systems is already known [3,10]. In the last years the number of published works where ABS is used to deal with real problems (no theoretical and armchair) has largely increased: supply chain management [27]; manufacturing [28,30]; finance [26] and natural resource management [8,9].

MAS have been shown to deal with problems of complexity, openness (components of the system are not known in advance, can change over time, and are highly heterogeneous and dynamic in project management terms), with dynamical and unknown environments changing over time (uncertainty) and ubiquity (the activity is distributed over the complete structure) [17,29].

Mes et al. [23] demonstrate that 'agent-based scheduling' can perform as good as or even better than traditional methods in real-time transportation systems. Hodik et al. [13] show a real time application for both intra-enterprise and extra-enterprise production planning. Another similar application of agent-based scheduling is presented in [2] to provide a real-time decision support tool for engineering consultancy companies that have to manage a large portfolio of short-time projects simultaneously.

MAS have facilitated a new way to study the decentralized multi-project scheduling problem [1,19,21,15]. Recently, Confessore et al. [7] defined the Decentralized Resource Constrained Multi-Project Scheduling Problem (DRCMPSP) which considers a set of projects, each one composed of a set of activities, with precedence relations, requiring specific amounts of shared renewable resources. This work has been followed and extended by Homberger [14] who proposes a new generic negotiation-based mechanism to coordinate project planning software agents to share resources among projects.

In the case of multi-project systems, the tasks, resources and project managers can be modelled as artificial agents. Such design enables to distribute the management system in elemental components directly identifiable in the target system, and hence giving the opportunity to create systems easier to design, to adapt and to maintain. Moreover, since the system is distributed according to its structure, any change in the structure can be easily translated to the management system.

This decentralized approach facilitates the design of market mechanisms to solve the scheduling problem by means of distributed approximations [6]. Recently, Lee et al. [21] have proposed an agent based dynamic resource scheduling for mul-